Novel Quantum Optical Physical Unclonable Function with Ai-Driven Stabilization for FPGA-Based Authentication Systems

Himani Choudhary
Department of IT - Cyber Security, IGDTUW, Delhi, India
Gaurav Indra
Assistant Professor, Department of IT - Cyber Security, IGDTUW, Delhi, India

Abstract:

This paper introduces a novel, AI-stabilized Quantum Optical Physical Unclonable Function (QO-PUF) designed for secure hardware authentication on embedded platforms. The system exploits the complexity of coherent light scattering through a disordered TiO2-doped polymer medium to produce high-entropy, physically unclonable response patterns. To mitigate environmental sensitivity—such as thermal fluctuations, mechanical shifts, and optical misalignment—an 8-bit quantized convolutional neural network (CNN) is implemented entirely on a Xilinx Artix-7 FPGA. This CNN-based stabilization corrects distortions in real-time, reducing the bit error rate (BER) from 18% to below 2.1% under stress conditions. The architecture achieves rapid challenge-response evaluation in under 5 milliseconds, while consuming only 30% LUT, 18% BRAM, and 12% DSP, making it ideal for latency-constrained embedded security applications. Extensive testing across 50,000+ challenge-response pairs confirms high uniqueness, reproducibility, entropy (>0.995), and resilience against machine learning modelling attacks (<5% prediction accuracy). This work demonstrates the feasibility of scalable, self-correcting QO-PUFs for next-generation edge authentication systems and lays a foundation for secure, AI-enhanced photonic identity primitives.